The Hangman (Latah) Creek Water Resources Management Plan

# APPENDICES

May 19, 2005

# Appendix N

## Golder Storage Report/Reforestation Memo

Note:  The Golder Storage Report is attached as a separate document.

## *TECHNICAL MEMORANDUM*

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| **TO:** | Spokane County Conservation District and WRIA 56 Planning Unit | **DATE:** | November 5, 2004 |
| **FR:** | Golder Associates Inc. | **OUR REF:** | 043-1155-001 |
| **RE:** | WEPP Reforestation Analysis | | |

# Reforestation Alternative

Reforestation of the Hangman Creek Watershed (WRIA 56) is being considered as a storage option for augmenting streamflow during summer, low flow periods. The analysis of the reforestation alternative makes use of the U.S. Department of Agriculture Water Erosion Prediction Project (WEPP) hillslope model to determine the changes in runoff through reforestation of representative sub-basin areas. The WEPP hillslope model incorporates climate, hillslope, soil, and land use information to simulate daily water balance parameters such as runoff, soil evaporation, plant transpiration, deep percolation, and lateral subsurface flow. The model does not include a runoff routing component and is not capable of modeling subsurface flow.

We explore model simulations of eight representative hillslopes for the purpose of:

- determining if changes from current landcover to historic forest cover affect runoff,
- determining if it is possible to achieve an equivalent of 3 cfs additional streamflow in Hangman Creek through reforestation, and
- determining which sub-basins exhibit greater runoff benefit from reforestation.

## Benefits

Forested lands can experience lower surface temperatures due to decreased convective heat transfer from the ground and decreased net radiation, which can cause delayed snowmelt. The Hangman Creek basin experiences an average 19 inches of snowfall in January (Golder Associates, 2004) and often experiences temperatures near freezing, resulting in frequent snow accumulation and melt events. Reforestation of agricultural land could benefit the Hangman Creek watershed by decreasing surface temperatures enough to maintain snow depth and delay snowmelt. This effect could result in increased streamflow later in the season than would normally occur, thereby augmenting potentially low streamflow However, forested lands may also negatively affect runoff as they typically experience greater evapotranspiration, infiltration, and depression storage than do agricultural lands, given identical hillslope characteristics (Maidment, 1993).

# Identification of Representative Hillslopes

Representative hillslopes were developed using Geographic Information Systems (GIS) analysis. Digital maps of soils, current land cover, topography, and historical land cover were used to characterize each sub-basin and hillslope. A historic forest vegetation layer developed by the Spokane County Soil Conservation District was used to locate areas of historic forest cover. Only areas that were historically covered by forest, including cottonwood, ponderosa pine forest, or evergreen forest, and now used for agriculture, were considered for potential reforestation analysis. At least one representative hillslope was identified for modeling purposes in each of five sub-basins identified by Buchanan (2002). These sub-basins include Minnie Creek, Lower Hangman Creek, California Creek, Rock Creek, and Upper Hangman Creek. Figure 1 shows the location of each sub-basin. For three of the sub-basins, more than one hillslope type was representative of the area. As a result, a total of eight representative hillslopes were analyzed. The eight representative hillslopes range in elevation, slope angle, soil type, and land cover type. The locations of the hillslopes were chosen to ensure a range of characteristics. Table 1 summarizes the characteristics for each hillslope by sub-basin.

# Model Development

The WEPP model, developed by the U.S. Department of Agriculture, is a continuous simulation physically based soil erosion prediction model. The WEPP hillslope model was used to evaluate the effects of returning agricultural lands in the Hangman Creek watershed to mature forest. Two scenarios were simulated for each representative hillslope, one with the current land cover classification and one with mature forest. This section describes the WEPP model, including model assumptions that might impact model results, and discusses the methods used for model simulation.

### *Background and Modeling Methods*

The WEPP hillslope model contains several components and predicts snow depth and density, runoff, plant transpiration, soil evaporation, deep percolation, and lateral subsurface flow, among other parameters, which provide the context for evaluation of runoff changes due to reforestation. The hillslope model is best suited for hillslopes less than 100m in length; however, it is advantageous for this exploratory analysis because of its ease of use and the limited number of required inputs. The model generates daily climate using statistical methods that incorporate available gage data. The user provides soil, vegetation, and topographic information. The water balance model contains several components, including an evapotranspiration model based on Ritchie (1972), a snowmelt model first developed by the Army Corps of Engineers (1956,1960) then modified by Hendrick et al. (1971) and Savabi et al. (1995), and an infiltration model based on a modified version of the Green Ampt equation. Overland flow is simulated using an analytical solution to the kinematic wave equations. The model simulates the water balance using the above mentioned models for every combination of soil type and land cover type on the hillslope.

Two model simulations (current land cover and reforestation of historic forest) were performed for each of the eight representative hillslopes. Simulations were run for a 30 year period and daily output was processed to produce one year of daily averages for several parameters, including runoff, soil evaporation, plant transpiration, deep percolation, lateral subsurface flow, snow depth, and melt water. Calibration of the model was not performed because the model has been well calibrated for northern Idaho and northeastern Washington. Specific input parameters for soil and land cover types are provided and analysis to verify their accuracy in the Hangman Creek watershed was not conducted. Land cover and soil types were chosen to best correspond with actual sub-basin types. For example, if the actual soil type on a hillslope was a composite of several types, the most dominant type was chosen for modeling. Land cover types were also chosen to best correspond to documented land cover. For example, if the current land cover was classified as small grains, winter wheat was used for modeling.

Water balance components including runoff, plant transpiration, soil evaporation, and deep percolation were calculated and compared for each of the eight representative hillslopes to provide an understanding of their relative importance by sub-basin. It is important to note that detailed sub-surface hydrology routing cannot be performed with the WEPP model. Thus, the changes in runoff relate to changes in surface runoff only as a result of snowmelt and precipitation events. In addition, the hillslope model does not route runoff into a channel, thus changes in runoff represent only the total amount of water running off the hillslope.

Daily average depths in millimeters were calculated for each component over the 30 year simulation period for each of the eight representative hillslopes. Positive values indicate that the resulting daily average is greater as a result of reforestation, while negative values indicate a decrease as a result of reforestation. Runoff results are also presented in terms of monthly changes in volume in acre-feet (AF) and changes in rates of surface runoff in cubic feet per second (cfs). Surface runoff rates correspond to the total volume of runoff and may not directly translate into streamflow due to routing effects.

# Modeling Results and Analysis

Model results indicate that reforestation decreases surface runoff during most of the year, especially during summer months when evapotranspiration, or water consumed by plants through evaporation and transpiration, is high. Isolated periods of increased surface runoff do occur in most sub-basins in late winter, early spring as snowmelt is slightly delayed. Surface runoff in the Rock Creek sub-basin also increases during the spring snowmelt period of May and June, according to model results. This effect may be caused by delayed snowmelt due to cooling by mature forest. It should be reiterated however that because the WEPP hillslope model is unable to simulate subsurface flow, the model is driven by precipitation events, which limits the source of increased runoff during low flow periods predominantly to delayed snowmelt and rain events. Due to limitations of the model's capacity to deal with subsurface flow, details of the return of groundwater to the stream through reforestation are not known. The following sections further evaluate impacts of reforestation on surface runoff and other water balance parameters for each sub-basin.

### *Runoff*

Streamflow augmentation in the Hangman Creek watershed is most desirable during the low flow period from April-September. Changes in monthly rates and volumes of runoff for each sub-basin are shown in Table 2. As a result of reforestation, only Rock Creek shows potential for increased runoff during the period of interest, and only during spring months of May and June. Runoff increases are approximately 3.3 cfs for May and 4 cfs for June due to reforestation of 67,580 acres in Rock Creek sub-basin. Results, however, indicate a general decrease in runoff in mid to late summer in the Rock Creek sub-basin by up to 3 cfs in August due to higher evapotranspiration rates. The Upper Hangman sub-basin, in comparison, has a loss of runoff by as much as 12-13 cfs in August through reforestation.

### *Water Balance*

Results for all scenarios show significant increases in plant transpiration due to reforestation, largely during the spring and early summer months. In addition, soil evaporation generally decreases as a result of reforestation, because latent heat transfer and convective heat transfer are greater for agricultural land than they are for forested land (Maidment, 1993). Changes in water balances for each representative hillslope are described in more detail below.

#### **Minnie Creek and Lower Hangman Creek**

Throughout the year in the Minnie Creek and Lower Hangman sub-basins, there is little change in runoff between the forested condition and current land use condition, which suggests that runoff does not change significantly due to reforestation in these regions (Figures 2-4). Both the Minnie Creek sub-basin and Lower Hangman sub-basin appear to have a number of days of higher daily average runoff due to reforestation in late winter periods. However, this does not carry through to the low flow target period for streamflow augmentation.

Results show that plant transpiration in these sub-basins increases by approximately 200% during spring and summer months due to reforestation. This large loss of water during the spring and summer comes mainly from the model's simulated soil water content, because much of the calculated runoff comes from precipitation events. Daily average deep percolation generally decreases due to reforestation for most of the winter. Deep percolation is water that infiltrates below the subsurface and is essentially lost from the modeled system. Overall decreases in deep percolation may be attributed to decreased lateral movement of water due to trees. Deep percolation increases later n late winter and early spring. The transition from decreased to increased deep percolation may be attributed to later timing of ground surface thawing and snowmelt.

The Minnie Creek sub-basin is characterized as having moderate rates of infiltration, while the Lower Hangman sub-basin is characterized by high infiltration (Golder Associates 2004, Figure 17). Moderate to high infiltration rates make it possible for snowmelt to infiltrate and/or become lost to deep percolation and not translate into runoff. Also, reforestation delays snowmelt by several days and may contribute to an initial decrease in deep percolation followed by greater deep percolation, corresponding to the timing of snowmelt.

Reforestation also appears to cause a decrease in daily average soil evaporation overall. Soil evaporation includes water that is sublimated from the snowpack. During the low flow period, even though less water is lost to deep percolation and soil evaporation as a result of reforestation, increases in plant transpiration prevent increases in daily average runoff.

#### **California Creek**

The California Creek scenario shows little change in runoff due to reforestation during the flow period proposed for streamflow augmentation (Figure 5). Changes in plant transpiration, deep percolation and soil evaporation in the California Creek sub-basin exhibit similar trends as Minnie Creek and Lower Hangman Creek, however the magnitude of the changes are less significant. Reforestation causes a 150% increase in average plant transpiration, a smaller increase than seen in results from the Minnie Creek and Lower Hangman Creek scenarios. California Creek is characterized by moderate infiltration rates as opposed to moderate to high infiltration rates of the above-mentioned sub-basins, which may contribute to less significant changes in deep percolation.

### Rock Creek

The Rock Creek sub-basin is characterized by two different slope types. Reforestation causes an overall reduction in daily average runoff over the 30 year simulation period, but also causes increases in runoff at times during the late spring that may augment streamflow above the 3 cfs target increase.

Approximately 60 % of the reforestable area of the Rock Creek sub-basin is characterized by the Rock Creek (a) hillslope and 40 % is characterized by hillslope (b). A comparison of total monthly runoff from the combined (a) and (b) hillslopes indicate that runoff increases occur in May and June under the reforestation scenario (Figure 6, 7). Increased runoff in May could be the result of delayed snowmelt due to decreased convective heat transfer in forested areas. A comparison of simulated snow water equivalent (SWE), the liquid content in the snow pack, for hillslope (a) shows that SWE decreases in the beginning of the year, but increases slightly in April and May as a result of reforestation (Figure 8). The increase in June runoff may be attributed to delayed snowmelt and the resulting higher simulated SWE in March, April, and May in the forested scenario (Figure 9).

A total of approximately 3.3 cfs increase in runoff can be found through May and an approximately 4 cfs increase in runoff through June in the Rock Creek sub-basin. This increase of runoff is total volume from the hillslope without consideration of routing, thus the precise amount of cfs that will route to the stream channel cannot be determined.

Transpiration during late winter and early spring by the mature trees is less than transpiration by the current vegetation. Later in the spring and through summer, however, historic vegetation transpires more than the current vegetation types. As a result of this higher transpiration later during the summer, decreased runoffs in the Rock Creek basin up to approximately 3 cfs in August occurred as a result of re-forestation. Soil evaporation is largely decreased due to reforestation. Reforestation causes decreased deep percolation during much of the year, with the greatest difference occurring during mid- to late winter. Decreased deep percolation indicates less water percolating below the root zone.

### Upper Hangman Creek

The Upper Hangman Creek sub-basin has two representative hillslopes. While runoff in this sub-basin increases during winter periods, the reforestation scenarios show decreased runoff occurs during the flow period proposed for streamflow augmentation (Figure 10,11). Upper Hangman Creek is characterized by low infiltration rates. It is likely that snowmelt results in rapid runoff in this basin as a result of the low infiltration of the soils. As a result, any changes in timing of runoff due to snowmelt runoff are very limited in this sub-basin and still occur primarily during winter months under reforestation.

The reforested scenarios for this sub-basin result in increased average plant transpiration 2 to 3 times that of the current land use scenarios during summer months. In addition, an overall decrease in deep percolation occurs, with more significant decreases occurring mid-winter. Soil evaporation decreased overall in the fully forested scenarios, with more significant decreases occurring mid-winter and mid-summer, but did not compensate for higher losses in transpiration.

## Reforestation Costs

There are several factors that must be considered in reforestation costs such as site preparation, desired vegetation type and availability, as well as planting labor and maintenance.

According to historic vegetation maps developed by Spokane County Conservation District, the three historic land cover types that could be revegetated in the Hangman basin are evergreen forest, open ponderosa pine, and cottonwood. Species selection should not be finalized without a full site assessment and consideration of objectives by a forester or other management professional familiar with the area. The Hangman Valley area approaching Spokane, Washington, would only support ponderosa pine on many sites, and a mix of ponderosa pine and Douglas-fir on others (Ron Mahoney personal communication, October 13, 2004). It is too dry for white pine, and likely also for W. larch (Ron Mahoney pers. comm.). The upper watershed, especially in the agricultural areas, will only support ponderosa pine (Gerry Green, personal communication, October 18, 2004). Douglas fir and grand fir may grow, but would likely not persist in those areas.

Nursery grown seedlings can vary in price depending on type, size and source. The University of Idaho Nursery as well as local wholesale and retail providers, base prices mainly on plug size and number ordered. Assuming locally adapted seed is available, a one year old, container grown conifer seedling of 5.5 cu in plug (root) volume (90 ml), which is a typical size for the average reforestation site, costs $0.28 each if over 500 are ordered from the University of Idaho Forest Research Nursery (Dave Wenny, personal communication, October 14, 2004). They also provide a larger one-year old seedling (20 cu in (340 ml) plug volume) for $1.75 each designed for harsh sites). Cottonwoods and other hardwoods have increased costs. Table 3 details pricing from two local sources.

A clearcut artificially regenerated may take 300 – 400 seedlings per acre depending upon stock size (Dave Wenny pers. comm.). Interplanting or reliance on natural regeneration for partial stocking of some species would call for fewer seedlings, perhaps 150 – 200, per acre (Dave Wenny pers. comm.).

Site preparation costs vary a great deal with site, objectives, and constraints. Site preparation involves assessing the condition of the site including present vegetation, soil type, aspect, as well as types of animals present that may damage trees. Is there a great deal of slash that must be removed or merely minor duff reduction? Can it be done by hand, mechanical equipment, fire, or herbicide? Are there leave trees or advanced regeneration to be protected? Several hundred dollars per acre is common.

Planting costs vary from 25-45 cents per seedling or $1000 to $2000 per acre depending on site conditions, size of seedling, spacing, and availability of planting crews (Atkinson and Fitzgerald 2002). Dave Wenny with the University of Idaho indicated that planting costs would vary ($0.15 - $0.20 per seedling for 5.5 cu in seedlings), depending upon site acreage, planter's access, planting season, degree of microsite preparation required, and stock size.

Total revegetation costs including seedlings and labor are estimated at $500 to $2500 per acre, based on 400 seedlings per acre. Table 4 illustrates the wide range of total costs per acre by historic vegetation type in the Hangmen watershed. Other factors to consider in costs include current land use, wildlife presence, and seedling protection measures necessary. Maintenance may be required after planting to ensure continued survival and growth.  These could significantly add to regeneration costs.

***Summary***

Increased transpiration by trees makes reforestation in the Hangman Creek watershed for purposes of increasing stream flow during summer months generally undesirable.  Rock Creek is the only sub-basin that shows promise for reforestation as a means of streamflow augmentation. Increased runoff of 3 and 4 cfs a day occurs during the May and June time periods respectively in the Rock Creek sub-basin primarily due to delays in snowmelt runoff. However, in the same sub-basin decreased runoff of up to 3 cfs per day occurs in August as a result of increased plant transpiration. Reforestation of the 67,500 historically forested acres in the Rock Creek sub-basin to obtain increased flows during the May (3.3 cfs) and June (4 cfs) time period would cost an estimated $33,750,000 to $168,750,000. Further analysis of this alternative using a more complex watershed model with subsurface hydrology and stream routing may provide additional insight into this scenario if desired.

# References

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